

FERMI-SURFACE NESTING AND MAGNETIC ORDERING IN SmNi_2Ge_2

X-ray scattering provides a unique capability to determine complex magnetic structures when the scattering cross section is enhanced through resonance effects. We present a perfect example by investigating the incommensurate antiferromagnetic structure of Sm moments in SmNi_2Ge_2 . The magnetic ordering conforms to the topological nesting of the Fermi surface characterized by $\mathbf{q} = (0, 0, q_z)$. The value of q_z is temperature dependent and approaches ~ 0.775 r.l.u. near $T_N = 17.8$ K. The ordered moments are confined to the basal plane.

It is not common in solid-state physics to find a family of complex materials whose microscopic properties are explainable in terms of simple concepts. Rare-earth nickel germanides, however, do form such an isostructural group. Most of the moment-bearing members of this family undergo phase transitions at low temperatures, below which the magnetic moments of the rare-earth ions spatially order in delicate arrangements. These intermetallics have multi-atom composition and a rather complicated tetragonal structure. As a result, the electronic structure of these compounds is quite intricate, and their magnetic ground state is determined by a subtle balance of various interactions such as the long-range indirect exchange and single-ion crystal electric field effects. However, it has been observed for almost all of the members that the magnetic wave vector, the most salient characteristic of the magnetic structure, has a fixed symmetry (along \mathbf{c}^*) and is *incommensurate* to the lattice. Despite the complexities alluded to above, recent calculations of generalized electronic susceptibility have pinpointed the origin of this behavior. It was found that there exists a pronounced topological nesting (large surface areas separated by $2k_F$, where k_F is the Fermi wave vector, but parallel to each other) of the Fermi surface in these materials, which fixes the magnetic wave vector to be of the form $\mathbf{q} = (0, 0, q_z=2k_F)$, with q_z in the range 0.75-0.81 r.l.u. [1]. The primary objective of

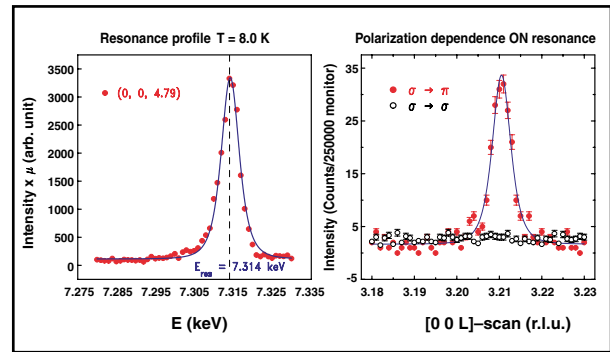


FIG. 1. Left: Energy scan through the Sm L_{II} edge of a superlattice peak. Right: Polarization analysis.

this experiment is to study the magnetic structures of the Sm member, which have not been studied before, to see if they agree with the nesting picture.

A rectangular crystal with dimensions $2.5 \times 0.9 \times 0.3$ mm³ was used for this study. The sample was oriented, cut, and polished perpendicular to $[0, 0, 1]$. Crystals of this material were grown by a high-temperature solution-growth technique [2] at Ames Laboratory. SmNi_2Ge_2 orders antiferromagnetically at $T_N = 17.9$ K and exhibits planar anisotropy above T_N . Another transition at $T_i = 11.8$ K is also clearly observed [3]. We performed x-ray resonant exchange scattering (XRES) [4,5] studies on the bending-magnet beamline in sector 1 of SRI-CAT [6]. Since Sm is opaque to neutrons and a high- Q resolution is crucial for studying incommensurate structures, XRES is ideal for the present study. The inci-

dent photon energy was tuned to the L_{II} edge (7.312 keV) of Sm in order to use the resonant enhancement. The (0, 0, 6) reflection from a flat pyrolytic graphite crystal was used as the polarization analyzer. Integrated intensities were measured using a Ge solid-state detector. The sample was cooled in a closed-cycle He refrigerator.

According to the nesting picture, the magnetic modulation vector is expected to lie along c^* , with a q_z value in the range mentioned above. A reciprocal lattice scan, at 8.0 K, revealed superlattice peaks corresponding to (0, 0, 0.79). Figure 1 (left panel) shows an energy scan through the satellite peak at (0, 0, 4.79). There is a strong resonance that occurs a few electron volts above the absorption edge, at 7.314 keV, with an enhancement factor of ~ 35 relative to the background ~ 25 eV below the edge. Polarization analysis (Fig. 1, right panel) revealed that the incident linear polarization perpendicular to the scattering plane (σ polarization) is completely rotated into the scattering plane (π polarization). The resonance and polarization properties indicate that the superlattice peak is magnetic in origin [2,6].

Figure 2 summarizes the temperature dependence of the ordered phases. The integrated intensity

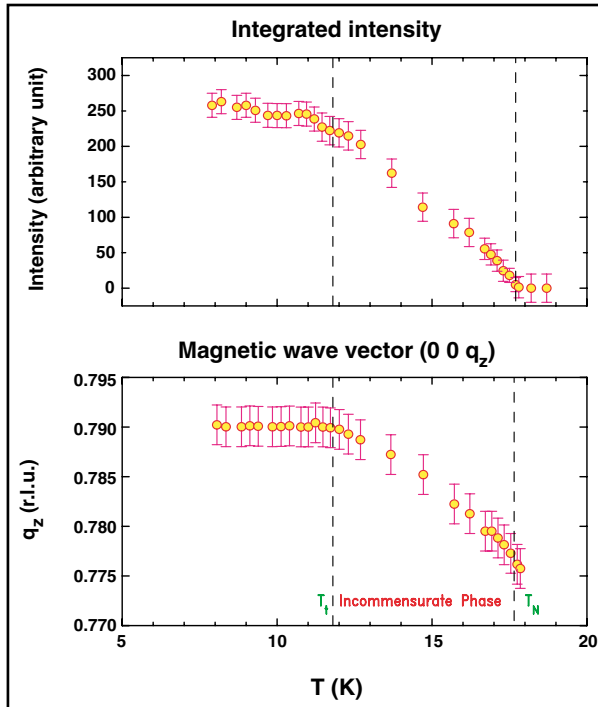


FIG. 2. Temperature dependence of the magnetic peak.

of the magnetic peak (top panel) remains nearly temperature independent below T_i , suggesting saturation of the ordered Sm moments. The intensity decreases monotonically above T_i and disappears above T_N . The lower panel shows the variation of the magnetic wave vector with T . In the phase below T_N but above T_i , the modulation vector changes continuously with T approaching ~ 0.775 r.l.u. near T_N , indicating the *incommensurate* nature of the ordering, consistent with the Fermi-surface nesting picture. Below T_i , however, the structure is characterized by a temperature-independent $\mathbf{q} = (0, 0, 0.79 \pm 0.002)$, suggesting a long-period ordered phase. Thus, T_i is

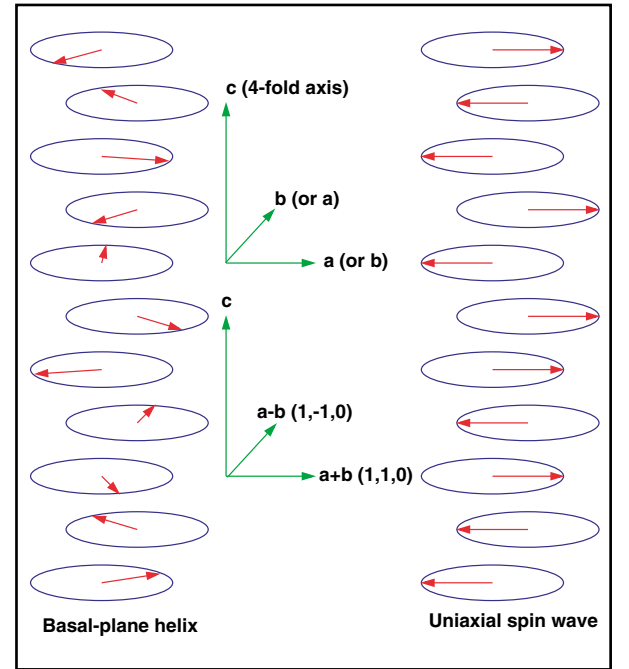


FIG. 3. Models for magnetic structures.

identified as the temperature at which q_z reaches this value with a concomitant near saturation of the intensity, which is 11.8 ± 0.2 K.

Finally, the anisotropy of moment directions was studied by measuring the intensity of a number of magnetic peaks. It was found that the ordered Sm moments are essentially confined to the tetragonal basal plane. Near T_N the moments are free to rotate in the basal plane, forming a helix (Fig. 3, left side) since the in-plane anisotropy is negligible. However, below T_i the moments may lock in along some crystallographic direction within the plane (Fig. 3, right side).

In summary, the primary result of this work is that the magnetic structures of the Sm member of the $R\text{Ni}_2\text{Ge}_2$ series conform to the topological nesting of the Fermi surface. SmNi_2Ge_2 orders in an *incommensurate* antiferromagnetic structure characterized by $\mathbf{q} = (0, 0, q_z)$. The value of q_z is temperature dependent and approaches ~ 0.775 r.l.u. near $T_N = 17.8 \pm 0.2$ K. The ordered moments are confined to the basal plane, as in the case of a basal-plane helix or a plane wave.

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